BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 11062

SUBJECT: IMEO Requirements for Conjunction Class Manned Missions to Mars, 1974-1993 - Case 105-3

DATE: November 24, 1969

FROM: C. L. Greer

ABSTRACT

NASW-417

A survey of opportunities for conjunction class manned missions to Mars from 1974-1993 was made. A nominal mission profile for each conjunction was chosen and the IMEO (initial mass in earth orbit) required for the nominal mission was computed assuming chemical stages and a vehicle sized for 6 crewmen. The maximum IMEO required in the time period studied is accommodated by three Saturn V launches. Total trip time is 1000 ± 100 days over all conjunctions studied. Time in Mars orbit varies from 320 days to 540 days. The missions of the late 1980's have times in Mars orbit greater than 500 days. Because of the 15-year synodic period of Mars, similar long times in Mars orbit should be available in the early 2000's.

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MEMORANDUM FOR FILE

Introduction

The standard classes of Mars missions are opposition class, conjunction class, and Venus swingby class. Of these three, the least studied is the conjunction class. This lack of attention is brought about by two characteristics of the conjunction class missions: the low energy requirements do not vary significantly with different conjunctions, and mission duration is on the order of 1000 days compared with about 500 days for opposition missions and about 700 days for Venus swingby missions. Two attractive features of the conjunction class missions are transfer trajectories which never pass inside earth's orbit or beyond Mars orbit and stay time at Mars of several hundred days.

The present study was undertaken to determine what IMEO (initial mass in earth orbit) would be required for conjunction class missions if Saturn V's and chemical rockets were to be used. Crew size was taken to be six and rubber stages were used in computing IMEO.* The number of Saturn V's required was based solely on the weight of payload to orbit and did not consider factors such as stack height limitations of the Vertical Assembly Building, etc.

Trajectory Calculations

The computer program IPROG2[1] was used to calculate the interplanetary transfer trajectories. This computer program uses conic sections to approximate transfer trajectories. The launch and arrival dates were varied over 200 day intervals, which were determined in the following fashion. For a specified conjunction date, arrival at Mars was permitted for a 200 day interval up to approximately 100 days before conjunction and departure was permitted for a 200 day interval starting approximately 100 days after conjunction. The shortest transfer time considered was 100 days. For example, the 1974 conjunction occurs on Julian date 244-2334. The arrival dates at Mars considered were 244-2040 to 244-2240, with earth launch from 244-1740 to 244-1940. The departure dates at

*A rubber stage is a stage of unspecified dimensions sized solely on the basis of payload weight and velocity requirements.

Mars considered were 244-2440 to 244-2640, with earth arrival from 244-2740 to 244-2940. These time intervals were searched at 20 day intervals. This produced 121 possible transfer trajectories from earth to Mars and the same number of transfer trajectories from Mars to earth. Table 1 is a compilation of Mars conjunction dates from 1974 to 1998.

An arbitrary selection of transfer trajectories was made to define a nominal mission which most nearly satisfied certain velocity constraints. The desired constraints for the nominal mission were V_∞ earth launch less than 4 km/sec, V_∞ Mars arrival and departure less than 3 km/sec, and earth entry velocity less than 40,000 ft/sec ($V_\infty \leq 4.85$ km/sec). The only constraint satisfied by all the nominal missions was the earth reentry constraint.

The trajectory characteristics for the set of nominal missions which best met the above criteria are described in Table 2. Two interesting details, total trip time and time in Mars orbit, which are computed from Table 2, are plotted in Figure 1. Total trip time is 1000 $\pm$ 100 days over all conjunctions studied while time in Mars orbit varies from 320 days to 540 days.

Initial Mass in Earth Orbit

The IMEO was calculated for each of the nominal missions under the following assumptions:

a) Rubber propulsive stages

b) I_{sp} of 460 seconds for planetary propulsive modules

c) Mass fraction .86 for propulsive stages

d) Mass of earth entry module, 15,000 lbs

e) Mass of mission module and laboratory, 70,000 lbs

f) Mass of Mars experiment payload, 50,000 lbs

g) Injection from 48 hour period earth parking orbit with periapsis altitude of 185 km (100 nautical miles)

h) Mars orbits considered were 12, 24 and 48 hour periods with periapsis altitudes of 185 km and 1000 km

The assumption of rubber stages was made for the sake of simplicity in this study. An I_{sp} of 460 seconds requires cyrogenics and for a conjunction class mission 700 days of

storage are required (i.e. through the Mars orbit escape phase). The module weights[2] are sized to accommodate a crew of six. The 48 hour earth orbit is selected to maximize the energy delivered by the Saturn V in burning nearly all the fuel in the SIV-B. The details of assembly in earth orbit, radiation hazard, etc., are described in Reference 3. It is assumed that a Saturn V can place 119,000 lbs. into such an orbit. For the six Mars orbits considered the maximum IMEO was required by the orbit with 12 hour period and 1000 km periapsis altitude. The minimum IMEO was required by the 48 hour orbit with 185 km periapsis altitude. These two extrema are plotted in Figure 2. There is slightly more than 10% variation in the IMEO over the nominal missions selected for a specified Mars orbit. The IMEO required is achievable with three Saturn V launches with 40,000 pounds excess capability for the maximum IMEO which is required for the 1985 mission.

Conclusion

The conjunction class missions have total trip time on the order of 1000 days. The missions of the late 1980's have more than 500 days duration in Mars orbit. The IMEO's required in this time frame are the largest of the conjunction class missions studied but, for the planetary vehicle weights assumed here, are well within the capability of 3 Saturn V launches. The 15-year synodic period of Mars is reflected in the time in Mars orbit graph. Hence, similar long stay times should be available in the early 2000's.

C. L. Greer

1034-CLG-blm

Attachments
Tables 1 & 2
Figures 1 & 2

REFERENCES

1. IPROG2 - Interplanetary Mission Profile Generator - P. F. Long, Bellcomm, Inc., 1-31-67

2. Private communication - P. L. Chandeysson, Bellcomm, Inc.

3. Tradeoff Study of New Cyrogenic Stage for Manned Planetary Exploration - Volume 1 - Summary Report - Douglas Aircraft Company, DAC-58052, September, 1967.

Table 1

MARS-EARTH CONJUNCTION

Calendar Date	Julian Date
October 14, 1974	244 2334.5
November 25, 1976	3107.5
January 20, 1979	3893.5
April 2, 1981	4696.5
June 3, 1983	5488.5
July 18, 1985	6264.5
August 25, 1987	7032.5
September 29, 1989	7798.5
November 8, 1991	8568.5
December 24, 1993	9347.5
March 4, 1996	245 0146.5
May 12, 1998	0945.5

Table 2

NOMINAL CONJUNCTION CLASS MISSIONS

EARTH DEPARTURE		MARS ARRIVAL		MARS DEPARTURE		EARTH ARRIVAL	
DATE	V_∞ (KM/SEC)	DATE	V_∞ (KM/SEC)	DATE	V_∞ (KM/SEC)	DATE	V_∞ (KM/SEC)
July 27, 1973	3.81	Feb. 12, 1974	2.92	July 27, 1975	3.30	May 2, 1976	3.24
Aug. 26, 1975	4.02	Aug. 10, 1976	2.50	July 16, 1977	2.92	May 12, 1978	2.86
Oct. 4, 1977	3.30	Sept. 9, 1978	2.47	July 6, 1979	2.68	June 10, 1980	3.13
Nov. 3, 1979	3.00	Aug. 29, 1980	2.68	Aug. 24, 1981	2.50	July 30, 1982	3.84
Dec. 2, 1981	3.00	Sept. 28, 1982	3.10	Dec. 12, 1983	2.77	Aug. 8, 1984	4.38
Dec. 12, 1983	3.84	Sept. 17, 1984	3.57	Feb. 19, 1986	2.44	Sept. 27, 1986	3.45
April 4, 1986	2.89	Nov. 16, 1986	3.16	May 9, 1988	3.22	Nov. 25, 1988	3.24
July 18, 1988	3.57	Feb. 3, 1989	2.56	July 8, 1990	3.48	April 14, 1991	3.39
Aug. 17, 1990	4.14	July 23, 1991	2.59	July 17, 1992	3.07	May 13, 1993	2.89
Sept. 25, 1992	3.45	Aug. 31, 1993	2.47	Aug. 6, 1994	2.74	June 2, 1995	2.98

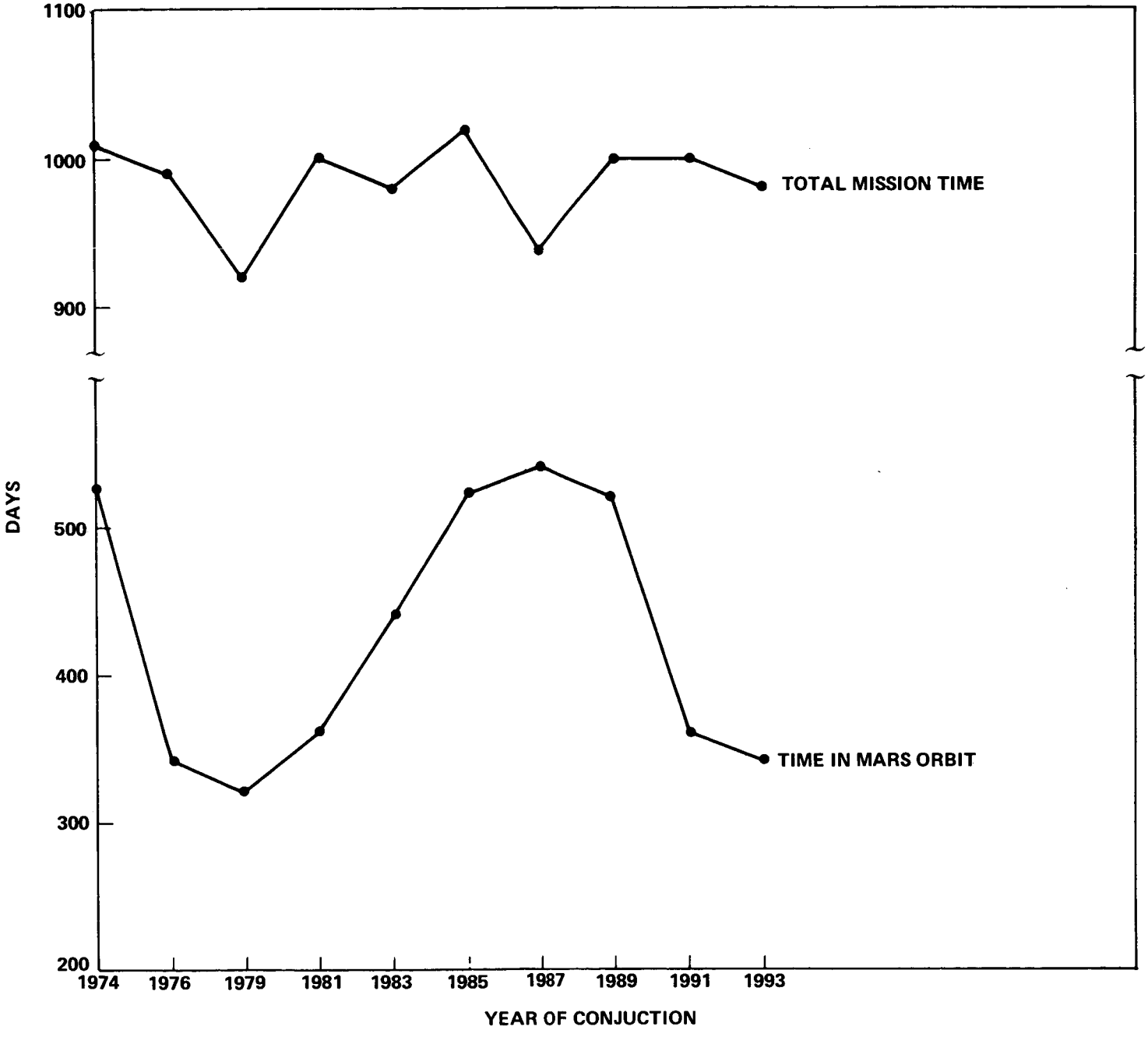
1100
1000
900
TOTAL MISSION TIME
DAYS
500
400
300
200
TIME IN MARS ORBIT
1974
1976
1979
1981
1983
1985
1987
1989
1991
1993
YEAR OF CONJUCTION

FIGURE 1 -

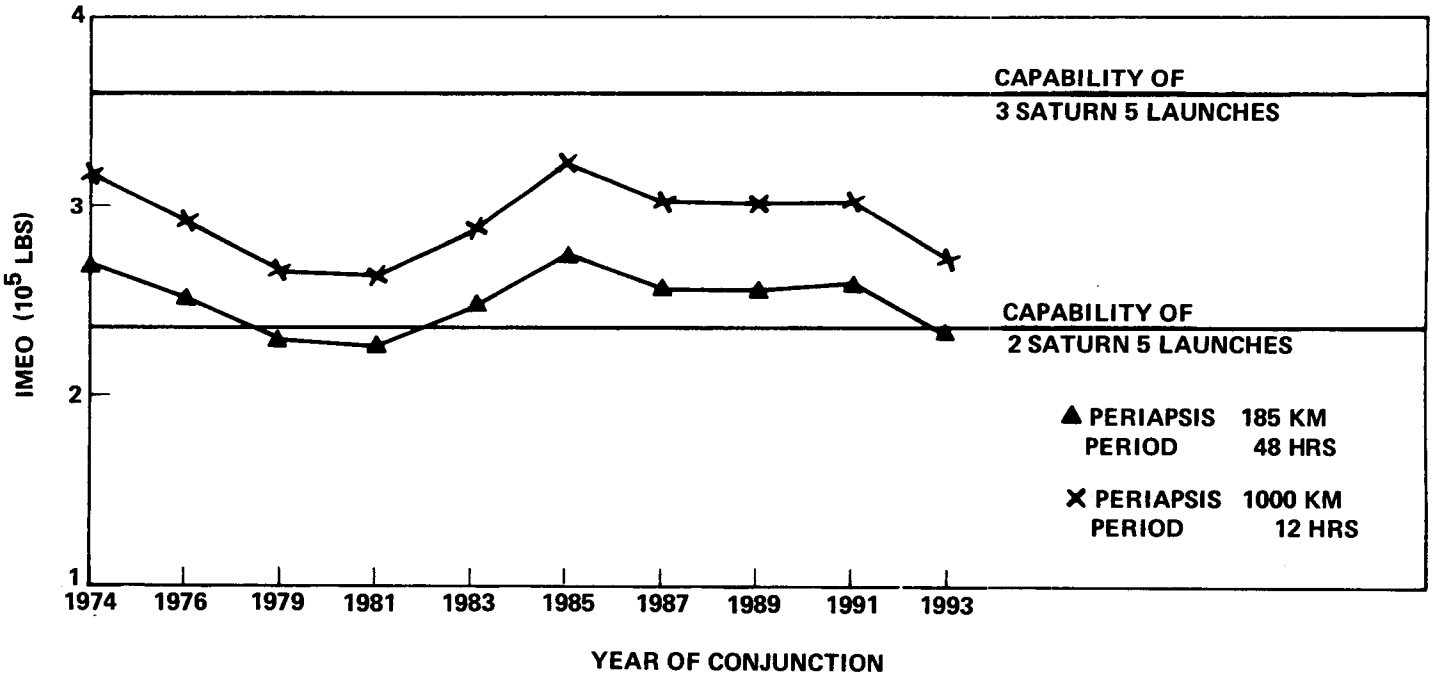
4
3
2
1
IMEO (10^5 LBS)
CAPABILITY OF
3 SATURN 5 LAUNCHES
CAPABILITY OF
2 SATURN 5 LAUNCHES
▲ PERIAPSIS 185 KM
PERIOD 48 HRS
✕ PERIAPSIS 1000 KM
PERIOD 12 HRS
1974
1976
1979
1981
1983
1985
1987
1989
1991
1993
YEAR OF CONJUNCTION

FIGURE 2

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FROM: C. L. Greer

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